
EPSRC
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*SUPERGEN Wind*

***Wind Energy Technology***

# Fault Analysis and Condition Monitoring for Wind Turbines: Practical Techniques for Wind farms

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***(on behalf of Loughborough, Durham and Manchester)***

Final Assembly
Holywell Park, Loughborough University
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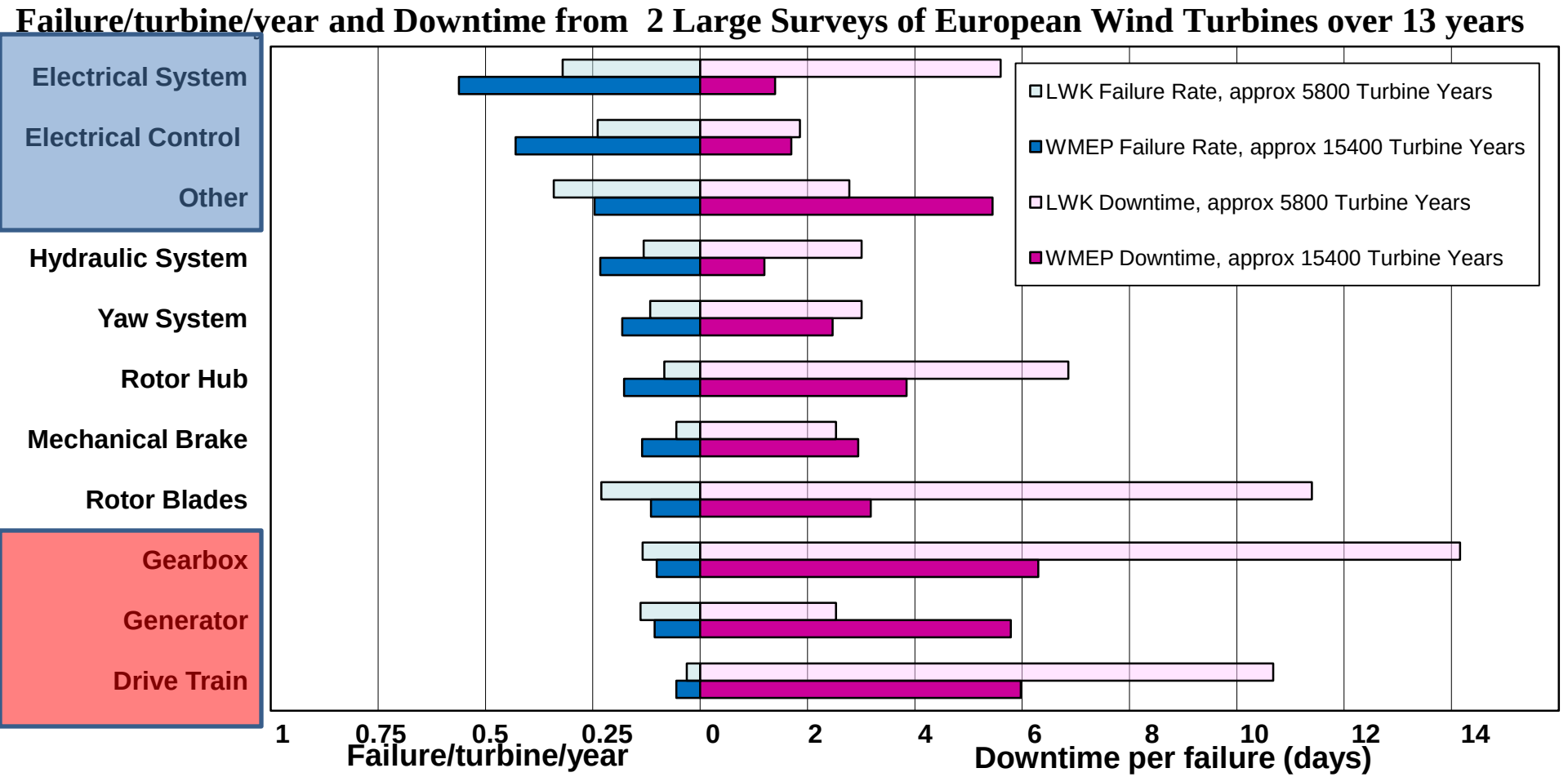
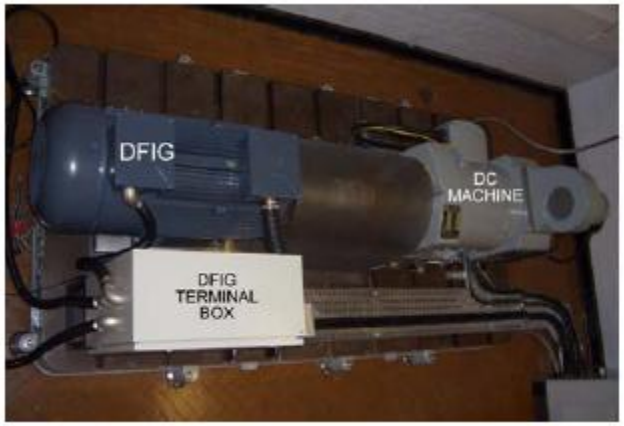
# Introduction

- Analysis of wind turbine failures
- Drive train monitoring
- Analysis of electrical signals
- Process modelling
- Physics of failure analysis
- Summary and recommendations

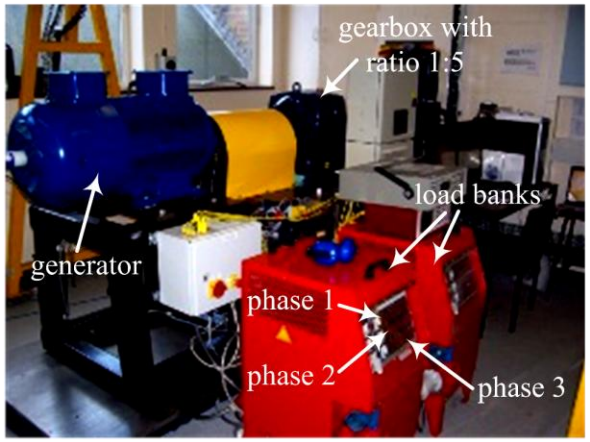
# Reliability & Downtime & Subassemblies, EU



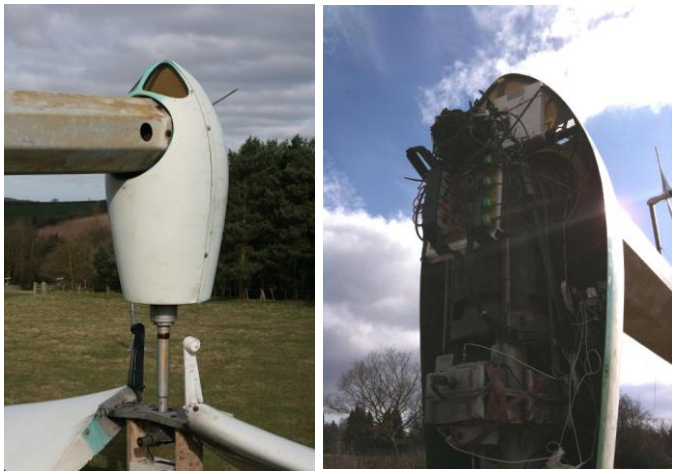
# Drive Train Test Data



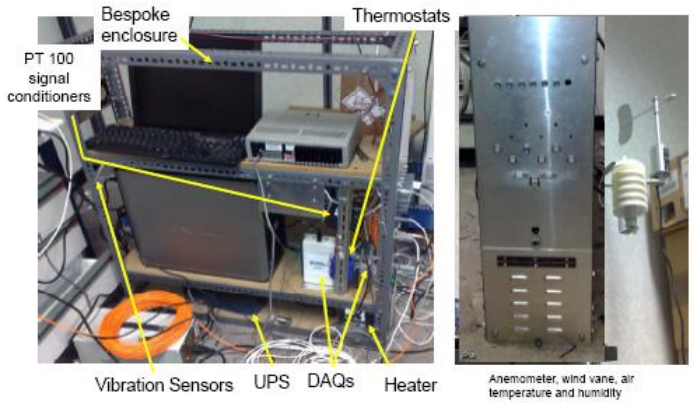

Electrical Generator Test Rig




Gearbox/Generator Test Rig



Small wind turbine CMS




Large wind turbine CMS

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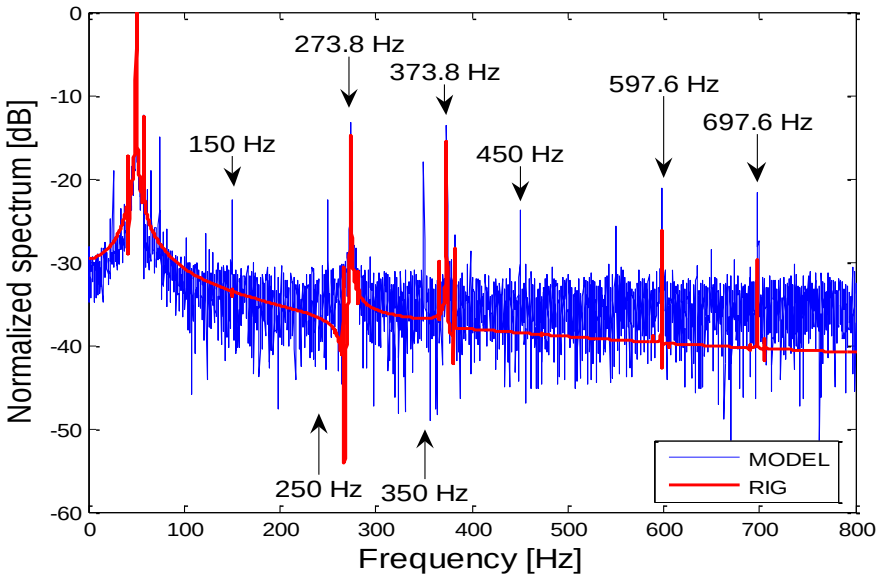
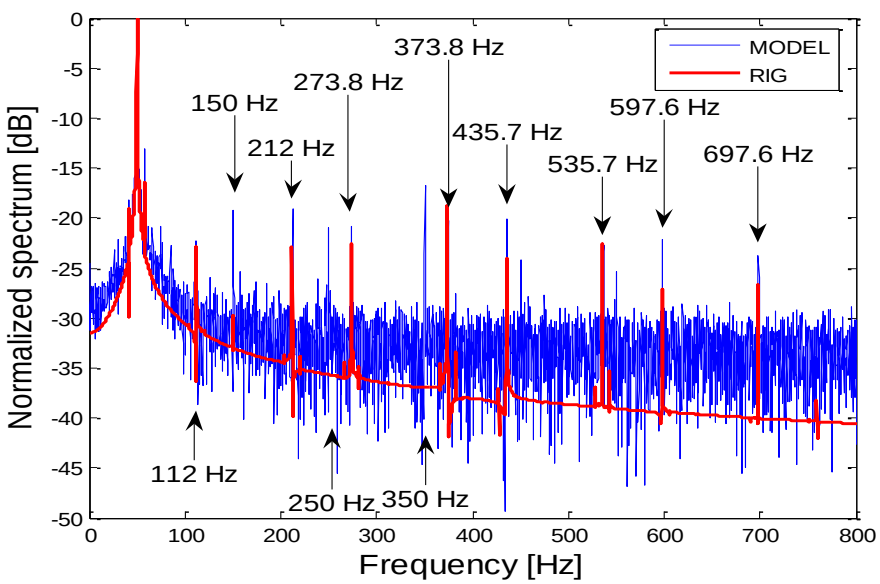
# Monitoring Generators

- Mathematical modelling
- Test rig simulations of faults
- Numerical analysis of test rig and real turbine data
- Validation against actual faults

# Frequency Analysis of Healthy and Faulty DFIG




a) Healthy DFIG




b) Stator winding open circuit fault

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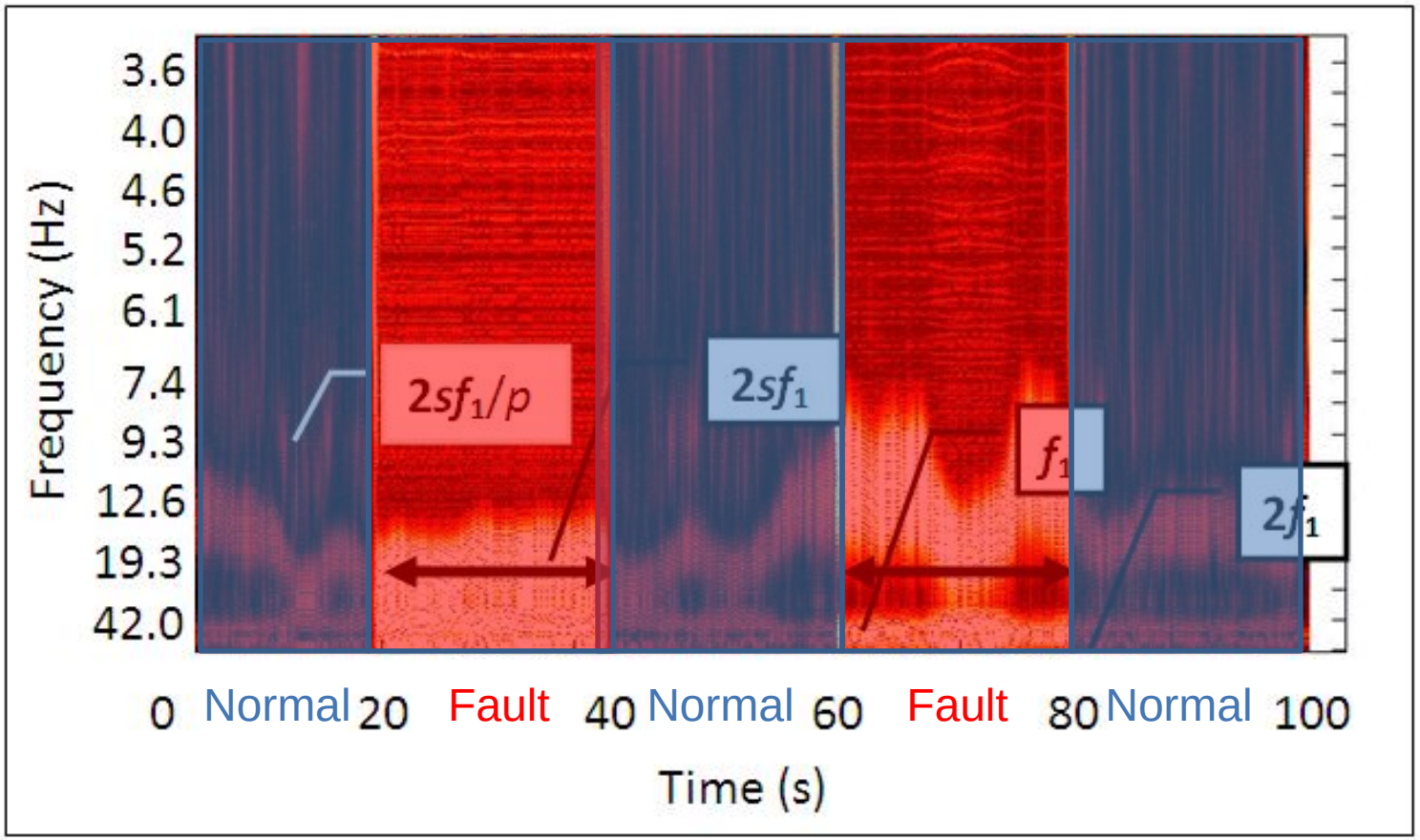
# Wavelet Analysis

- Extract particular component of electrical power signal using a wavelet
- Analyse magnitude of particular frequencies (which may vary in time) indicative of faults
- High magnitude indicates fault
- Generator misalignment leading to possible bearing failure

# Analysis of Test Rig Faults




$2sf_1$ - Relatively low frequency signal which can be monitored

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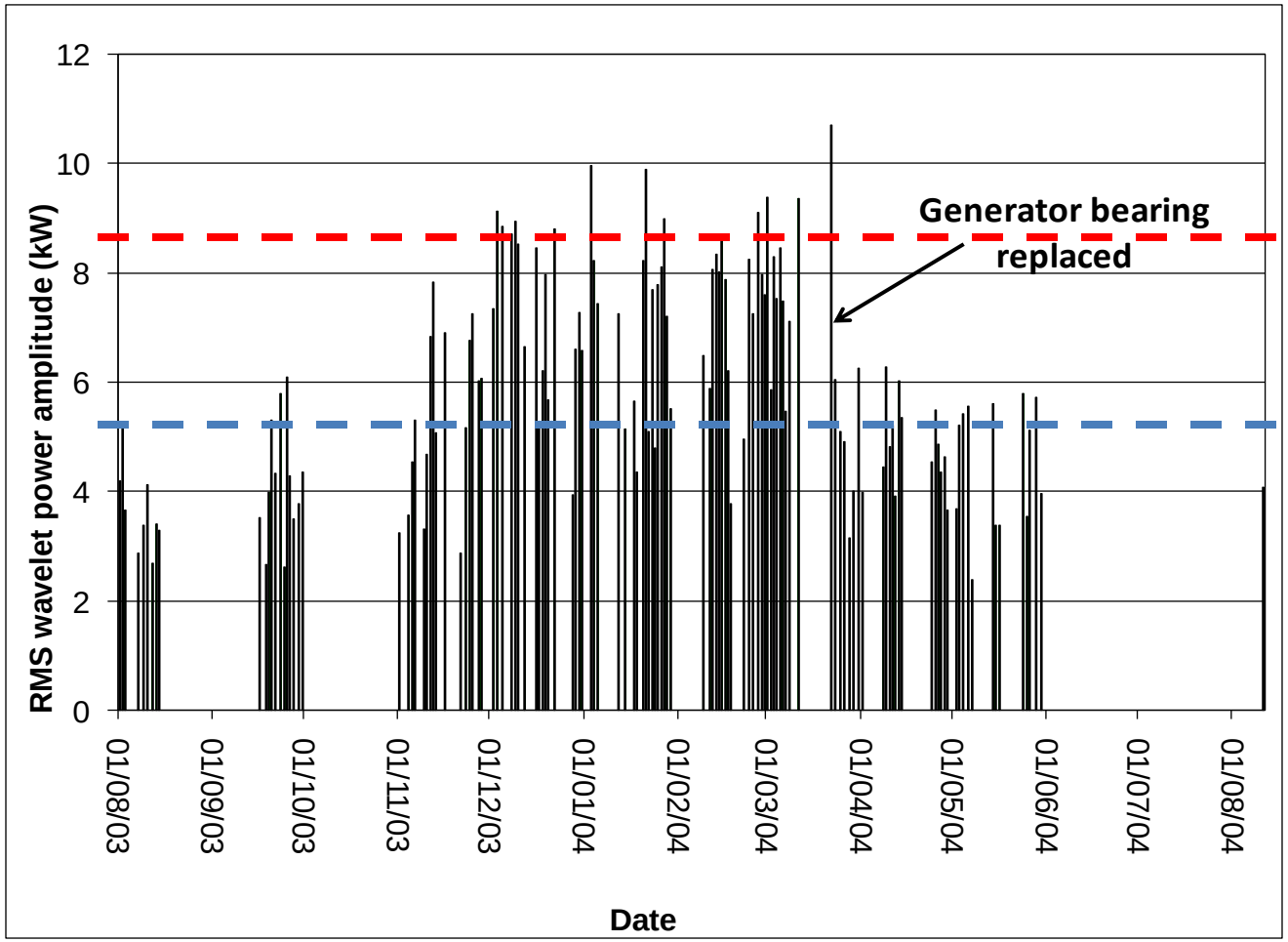
# Analysis of Real Turbine Data after the event




Faulty generator bearing

Normal generator bearing

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# Physics of Failure Using SCADA Data

- FMEA analysis to determine failures, causes and indicators
- Identify key failure indicators from data
- Develop theoretical damage model
- Monitor damage accumulation
- Determine probability of failure

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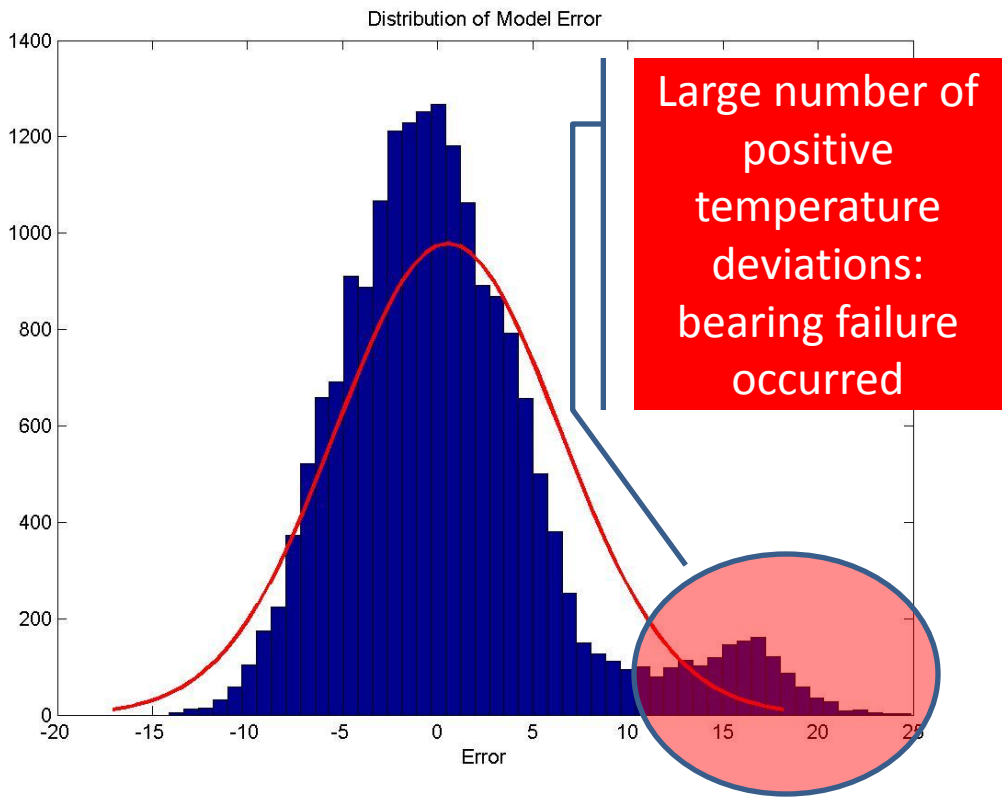
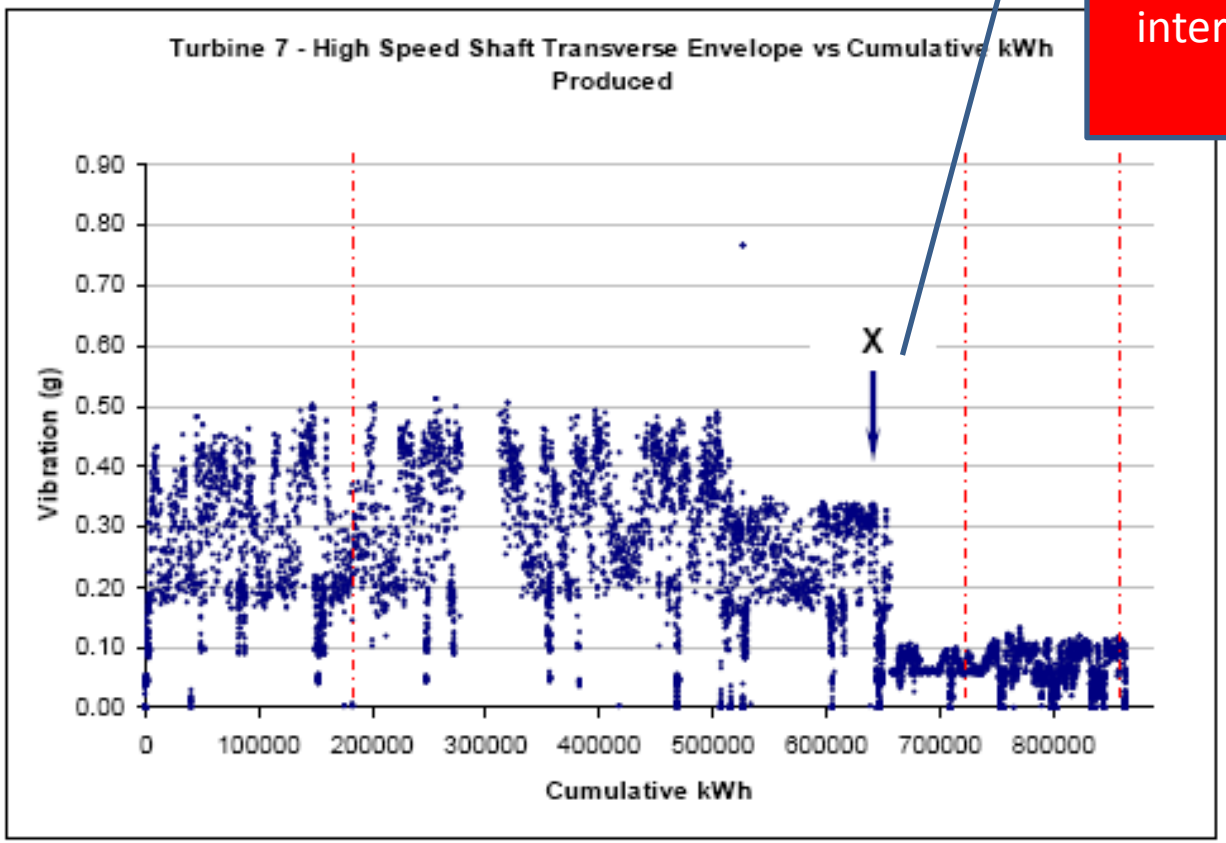
# Process Modelling Using SCADA Data




- Time series process model of generator bearing temperature
- Compare actual with prediction
- Discrepancy possible indicator of fault

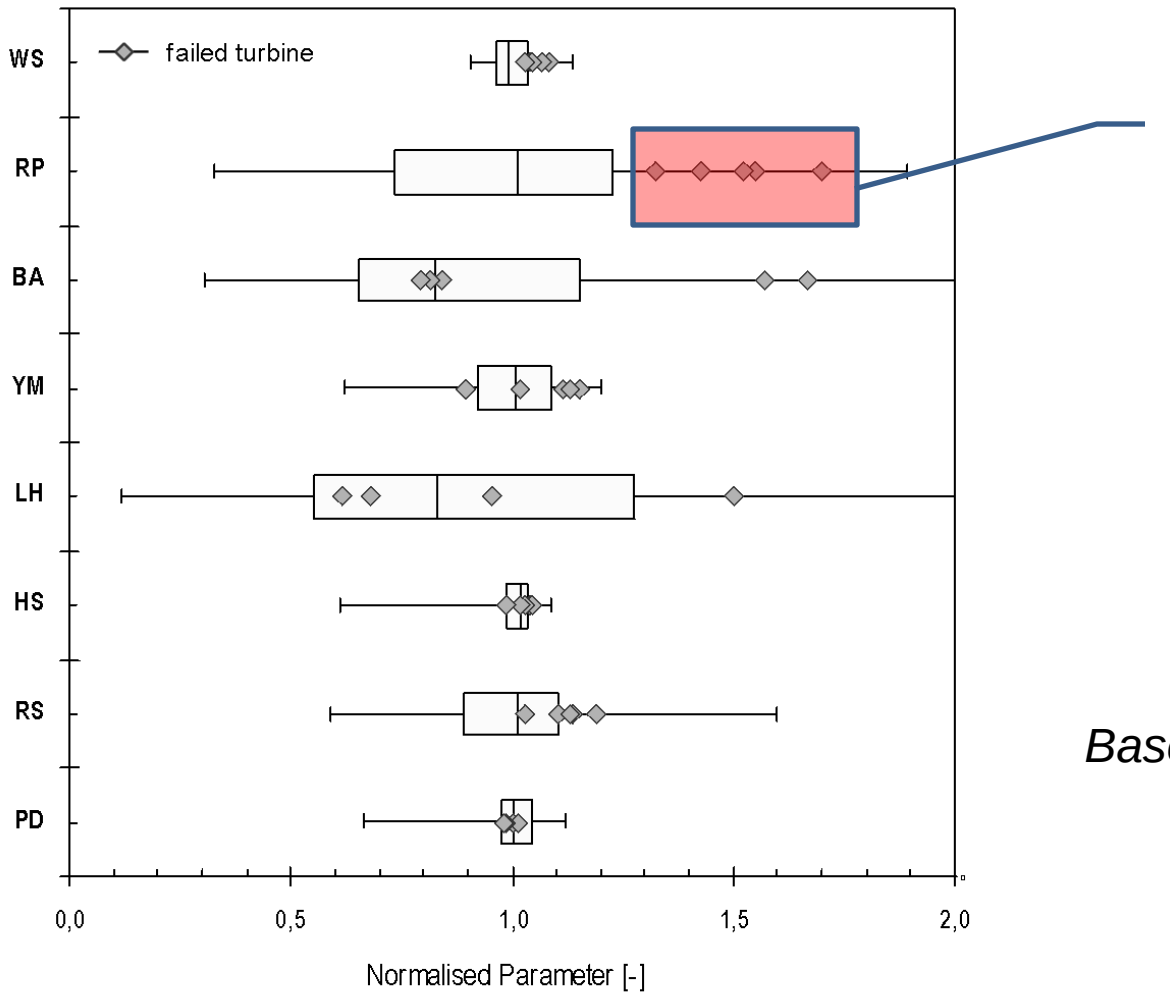
# Analysis of Real Turbine CMS Data After the event Gearbox Bearing Failure




Brass bearing cage on intermediate stage collapsed

Figure 4 - Gearbox High Speed Shaft Transverse Vibration Envelope against cumulative energy produced

# Gearbox Failure SCADA Data



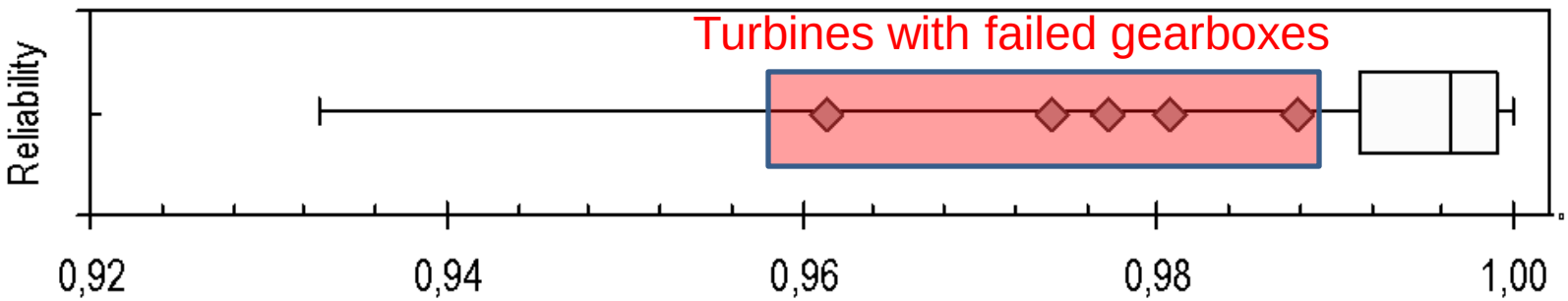

**Turbines with failed gearboxes in top 25th percentile in terms of hours at rated power:**

*High cycle fatigue due to poor contact conditions between roller and raceway and occurring at conditions of high stationary power*

*Based on a large US wind farm*

# Damage Model - Reliability

Damage Accumulation Model Based on Electrical Power and Rotor Speed




*Distribution of calculated reliability based on damage calculation for specific failure mode "bearing High Cycle Fatigue due to edge loading"*

# Summary and Recommendations

- Drive train key focus for condition monitoring
- Electrical power (high, medium, low frequency – give different information), temperature, oil and vibration monitoring
- SCADA data valuable for process and damage modelling
- Combined approach – use several indicators to give confidence in prediction of the probability of failure of subassemblies